

TUCKER (W. G.)

Compliments of
WILLIS G. TUCKER, M. D.

als

THE
PURIFICATION OF WATER
BY
CHEMICAL TREATMENT.

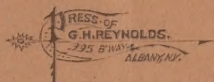
BY

WILLIS G. TUCKER, M. D., PH.D.,

Professor of Inorganic and Analytical Chemistry in the Albany Medical College.



REPRINTED FROM THE ALBANY MEDICAL ANNALS,
APRIL, 1892.



THE
PURIFICATION OF WATER

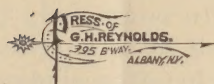
BY

CHEMICAL TREATMENT.

BY

WILLIS G. TUCKER, M. D., PH.D.,
Professor of Inorganic and Analytical Chemistry in the Albany Medical College.

REPRINTED FROM THE ALBANY MEDICAL ANNALS,
APRIL, 1892.



THE PURIFICATION OF WATER BY CHEMICAL TREATMENT.*

BY WILLIS G. TUCKER, M. D.

PURE water does not exist in nature. It is an ideal substance to which the purest water that can be prepared by the chemist only approximates. From a chemical standpoint every foreign substance which water may contain is an impurity, but hygienically considered, water is called impure only when it contains excessive amounts of mineral matter in solution or in suspension; when it contains organic matter of vegetable or animal origin, or the products of the decomposition of such matter in quantities exceeding certain generally accepted but rather arbitrarily assigned limits, or when it is shown to contain living organisms believed to be associated with or productive of diseases which water may communicate. All filth in food or drink is to be abhorred, but, none the less, distinction must be made between that which, containing or accompanying specific disease germs, may give rise to specific diseases, and that which is, while not unobjectionable, yet apparently incapable of materially affecting health. The chemist is as yet unable to distinguish disease-producing from relatively harmless impurities in water. He can recognize those constituents which indicate organic pollution; demonstrate the present existence of putrescent material, or show that such material has previously existed by the recognition of the products of its decay, but he can by no means assert with certainty that any given water will necessarily give rise to disease or will certainly prove to be wholesome. Waters containing putrescent organic matter of animal origin have been

*Read before the Medical Society of the County of Albany at a meeting held February 23, 1892

drunk without harmful results. Such cases are on record, and on the other hand, waters which analysis has shown to be of fair chemical purity have unquestionably given rise to disease. Nevertheless the chemical analysis of drinking waters, despite the limitations and imperfections of our best processes, furnishes most valuable information, in no other way to be obtained, and I shall spend no time in a defense of this method of investigation. There are unmistakable signs of pollution which analysis may reveal and such warnings should not go unheeded. If it be shown that a well receives the leachings of a privy-vault or cesspool, or that a running stream is contaminated by sewage, as yet unoxidized and possibly infectious, such water should be condemned and neither chemist nor bacteriologist should be required to demonstrate its disease-producing power. Indeed this would be in most cases entirely impossible, such proof being seldom attainable.

Impurities in water exist in suspension or solution, and may be either inorganic or organic. Suspended matter may frequently be removed, wholly or partially, by mere sedimentation or by some simple process of filtration, but matter which is held in solution must be destroyed or removed in other ways. The boiling of water may produce a deposition of some of its earthy salts; a coagulation and precipitation of some of its organic matter and a destruction of its micro-organisms including disease germs if present, and while this method of purification is frequently serviceable as a household measure it is not adapted to use upon a large scale. By distillation a still further purification may be effected, but this is a still more costly process and can never come into general use. Within a few days I have examined a sample of distilled water prepared and sold in bottles for table use in which, while the free ammonia was high, the albumenoid ammonia was very low; chlorine, nitrites and nitrates absent, and total solids almost nil. Such water is as pure as can well be made on a commercial scale but it is necessarily too expensive to be commonly used. Aeration has likewise been resorted to for the destruction by oxidation of organic matter and is said to have been employed more than a century ago by Lind on the west coast of Africa. Considerable improvement has been effected in certain city supplies by pumping

air into the mains or reservoirs or by discharging water in jets or fountains into basins so as freely to expose it to the air. Where waters are shown to be deficient in dissolved oxygen, especially in the case of impounded waters in which patches of green algae appear upon the surface in warm weather, such treatment is often of the greatest value. It is an imitation of a natural process of purification and the change effected is not to be regarded as purely chemical, being brought about by bacterial organisms, the nitrifying bacteria, which, under favorable conditions and in presence of free oxygen, convert nitrogenous organic matter into harmless inorganic forms.

The purification of polluted water by direct chemical treatment has been effected with more or less success in many ways, all practical methods involving the separation of precipitated matter either by sedimentation or filtration after treatment of the water. In other words, there is no chemical agent which, by simple addition to impure water, will render such water pure and wholesome. By chemical treatment we may precipitate lime and other earthy salts if present in undue quantity; coagulate and remove organic matter and bacteria, or promote the oxidation of such matter, and various processes accomplishing, more or less perfectly, these results, have, during recent years, been employed.

Clark's process, designed particularly for the softening of water owing its hardness to bi-carbonate of lime, consists in the addition of milk of lime, which results in the formation of an insoluble carbonate subsequently separated by sedimentation. Colored and turbid waters are clarified and organic matter and living organisms largely reduced by this treatment, as has been shown by Dr. Percy F. Frankland, (*Chemical News*, vol. 52, p. 40.) and others, but if much organic matter is present the precipitation does not readily occur and filtration must be resorted to as in the Porter-Clark process. Other methods for softening water involve the use of caustic soda in addition to slaked lime, as in Howatson's process and the use of tri-sodic phosphate, now a commercial article, by which means the salts producing permanent hardness are largely removed, and in the household carbonate of soda (washing soda) is employed for the same purpose,

though its use is impracticable on a large scale on account of the expense.

Such methods as these however are primarily intended for purifying water for laundry use, manufacturing purposes and making steam. They are more important from a technical than from a sanitary standpoint and we pass from these to speak of those processes in which the main object is the removal of constituents believed to be harmful to health. Before so doing, however, a few words concerning filtration may not be out of place, the more especially as either sedimentation or filtration is generally necessarily connected with every process intended for the purification of water. Filtration which is a mere straining, as for example continuous filtration through sand or animal charcoal, may clarify a water without otherwise improving it in any respect, and if, after a time, the filter becomes foul, the water may be polluted rather than improved. I regard with disfavor most of the old-fashioned filtering appliances, which not only gave a false sense of security, but often served as breeding-places for the growth of living organisms. A house filter which is not easily cleansed is an abomination, being generally allowed to take care of itself and in time becoming a source of real danger. A few years ago a case of no little interest was reported in the *Chemical News* (vol. 52, p. 70). Two samples of water were analyzed for a family in which one member was ill with typhoid fever. One of the samples was from the house supply direct and the other was the same water filtered through a portable charcoal filter of the common type. This latter sample yielded a much larger amount of albumenoid ammonia than the former; decolorized five times as much permanganate of potassium and was in every respect objectionable. On inquiry it was learned that the filter had been in use for more than a year, and that in the place where the owner had formerly resided he had found the water so bad that he had made use of it to filter that which he used for his bath. A few years ago when typhoid fever prevailed in Providence, R. I., and seemed not to be fairly attributable to the city water supply, Dr. T. M. Prudden, examined several of the filters used in private houses and found the typhoid bacillus in no less than three of them. (*New York Medical*

Journal, vol. 50, p. 14.) Filters giving such results, it need scarcely be said, are a constant menace to health, but those which allow of easy cleaning by reversed currents of water are free from most of the objections attending the use of the older forms. Five years ago I analyzed some samples of Albany water, filtered through a well-known filter manufactured in this city (the Blessing Duplex Filter), and found that a sample of water obtained by washing the filter after a day's use, yielded of albumenoid ammonia, 0.1850 parts per 100,000, showing that the filter had retained a large amount of organic matter. Water which had passed through the sand of the filter only, yielded 0.0023 and that which had passed through both the sand and charcoal yielded but 0.0014 parts per 100,000. This latter quantity is about one-tenth that ordinarily found in our city water and this is certainly a very good showing. Two years since I analyzed water which had been drawn from our upper service, both before and after filtration through the same filtering apparatus, and found the free ammonia reduced to a fifth; the albumenoid ammonia to a fourth and the oxygen absorbed to two-thirds of the amounts originally present, by filtration, while a sample of water from the lower city service had its free ammonia reduced to a fifth; albumenoid, to a tenth and oxygen absorbed to a twelfth, indicating a vast improvement in a water at that time in singularly bad condition. These results I believe to be largely due to the efficient action of the animal charcoal, which in this device acts, not as a strainer or filtering medium proper, but as an oxidizing agent, provision being made for its constant aeration. In many filtering appliances animal charcoal is a fruitful source of trouble and danger, but if the real filtration is accomplished by other material and the coal is subjected to frequent aeration and renewed when necessary, it is a most valuable agent for effecting the oxidation of organic matter. I purpose soon to make some experiments with a view to determining how long animal charcoal retains its activity in such filters, though it is very certain that, with proper treatment, it will continue to operate satisfactorily for a long time.

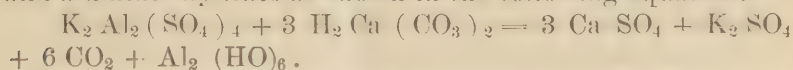
Of the chemical agents which have been employed in water purification the most important are metallic iron, solu-

tions of iron salts, generally the chloride, permanganate of potassium and alum. Spongy iron, obtained by the reduction of hematite ore at a temperature a little below that of fusion thereby rendering the metal porous or spongy in form, was first made use of by Bischof, whose process was patented in England in 1871, though Dr. Medlock had secured a patent in 1857 for a process of purification based upon the use of metallic iron plates, and Spencer in 1867 introduced a material which he called magnetic carbide in which the active agent was iron. The carbonic acid in the water, acting upon the iron in one or the other of these forms, produces a ferrous carbonate, which, by oxidation yields hydrated ferric oxide, and this is believed to effect the oxidation of organic matter and serve as a coagulant as well, producing a flocculent precipitate which is subsequently separated by sedimentation or filtration through sand. Such methods have been employed with more or less success in various European cities, but Anderson's process, which has been successfully used at Antwerp, Ostend, Paris and Vienna, has generally replaced other methods of purification by iron. In this process the water is forced through revolving purifiers consisting of iron cylinders revolving on hollow trunnions which serve for inlet and outlet pipes. On the inner surface of the cylinders are curved ledges running lengthwise, which scoop up and shower down through the water fine cast iron borings as it flows through the cylinder so that every portion of the water is brought into contact with the iron which is kept constantly bright and clean by attrition. The water issuing from the purifiers is exposed to the air, by allowing it to flow through a trough, to secure the precipitation of the ferric hydrate, and by filtration through sand this precipitate is subsequently removed. It is claimed for this process that the organic matter is altered in form and largely destroyed, the albumenoid ammonia being reduced to from one-half to one-fourth, and micro-organisms largely destroyed or removed. At Antwerp 2,000,000 gallons daily are thus treated and Professor Edward Frankland has shown that this water is completely sterilized and nearly all its organic matter removed. The cost, previous to the introduction of settling reservoirs before filtration, has been \$4.00 per million gallons.

In a paper read before the Franklin Institute in 1890 by Easton Devonshire, C. E., it is estimated that the cost of working expenses, with an output of 5,000,000 gallons per diem or over, should not exceed \$2.00 per million.

Ferric chloride has been employed in Holland for removing clayey matter and organic impurities from the water of the Maas which supplies Rotterdam. Carbonate of iron is formed and decomposed with separation of ferric hydrate which coagulates and removes the organic matter, but such treatment is attended with many difficulties and is not likely to come into general use. The same may be said of the employment of permanganate of potassium which oxidizes organic matter and by its decomposition yields manganic hydrate which precipitates much of the suspended matter present in the water. Such processes may be successful, here and there, on a small scale, but they cannot as yet be practically or economically employed in the purification of large supplies.

The only other purifying agent of which we need speak is alum. It is said to have been used for centuries in China and India, but particular attention was first directed to its use by Jennet in 1865. Most waters contain more or less bicarbonate of lime in solution and the alum acting upon this constituent yields sulphate of lime, carbonic acid gas and aluminic hydrate as shown in the following equation:



As the aluminic hydrate forms and deposits it not only entangles and carries down finely divided suspended mineral matter but coagulates and removes much of the dissolved organic matter as well. By this means peaty and other colored waters are decolorized; turbid waters containing finely divided clay are clarified and bacteria removed. Professor A. R. Leeds in an experiment performed upon the water used at Mt. Holly, N. J., found that alum, added in the proportion of half a grain to the gallon, produced the following effect: "On standing the peaty matter was entirely precipitated in reddish-yellow flakes and the water above became perfectly colorless and clear. On pipetting off some of this supernatant fluid I found that instead of containing 8,100 colonies of bacteria per cubic centimeter, as it did before

precipitation with alum, it contained only 80 colonies. On filtering some of this supernatant water through a double thickness of sterilized filter paper into a sterilized tube I found no bacteria in the filtered water. In other words the water had been rendered by the addition of an amount of alum so minute as to be inappreciable to taste and almost to chemical tests, *as sterile as if it had been subjected to prolonged boiling.*" (*Journal American Chemical Society*, ix, p. 154.)

Austen and Wilber made a valuable report to the State Geologist of New Jersey in 1885, on the "Purification of Drinking Water by Alum." They found that 1.2 grains per gallon was sufficient for the complete precipitation and clarification of the New Brunswick city water, if sufficient time was allowed for settling. Such an amount is imperceptible to the taste and can exert no physiological action. If more alum is used less time is required for sedimentation and vice versa. More than two grains to the gallon was seldom required. They showed likewise that waters which will not yield clear filtrates on account of their containing finely divided clayey matters, even when filtered through the finest filter paper, were immediately coagulated and precipitated by 1.16 grains of alum to the gallon, so that they could be filtered immediately after adding the alum, yielding brilliantly clear filtrates, and, in their opinion, no more than twice this quantity, or about two grains per gallon at most, need ever be employed.

In January, 1889, a sample of peaty water from Athol, Mass., having a decided yellowish-brown color, was submitted to me for examination. Difficulty had been experienced in clarifying this water by filtration and I made some experiments to determine the action of alum upon it. Our city supply was at that time yellowish in color and slightly turbid, and this was also tested. It was found that, in both cases, the addition of alum in the proportion of 2.3 grains per gallon gave rise at the end of twenty-four hours to a yellowish flocculent deposit, undergoing no further change on standing for four days, the water becoming clear and almost perfectly colorless. The waters were tested again by adding the alum, shaking in a flask and immediately filtering through paper. The city water became transparent and perfectly colorless and the peaty water retained but a very faint, almost impercep-

tible, yellowish tint. The peaty water yielded originally 0.0225 parts of albumenoid ammonia per 100,000, but after the addition of alum, agitation and filtration, it yielded but 0.0060 parts, or about one-fourth as much, showing how great an improvement had been effected.

For household use on a small scale water can be easily clarified and purified by placing a layer of clean cotton, two or three inches deep, at the bottom of a glass percolator, such as is used by druggists, and pouring the water to be filtered, to which solution of alum has been added, into the percolator and allowing it to drip through into a clean vessel placed to receive it. The alum solution is conveniently made by dissolving half an ounce of alum in a quart of water, and of this solution a scant teaspoonful should be added to each gallon of water to be filtered. Alum is now used in a number of filtering and purifying systems which have of late years been brought prominently before the public by their inventors or the companies controlling them.

If now it be asked, do such processes as these which we have described, admit of practical and economical application to the purification of large volumes of polluted water for the supply of our great cities, I fear that an unqualified affirmative answer can hardly be given. In American cities the consumption of water is much greater than in European towns. The *Encyclopaedia Britannica* states that "the consumption varies greatly in different [English] towns, ranging from about twelve to fifty gallons per head per day," and that "an ample supply for domestic use and general requirements is from 20 to 25 gallons per head daily." With us a hundred gallons is frequently supplied. Albany wants 15,000,000 gallons with a population of less than 100,000. Philadelphia and St. Louis consume 70 gallons; New York, 80; Boston, 90; Chicago, 115 and Detroit 150, while Glasgow, Dublin and Edinburgh consume but 50, ; London, 40; Birmingham, Leeds and Liverpool about 30 and Manchester and Sheffield still less. On the continent it is about the same. Paris uses about 50 gallons; Hamburgh and Dresden, 60 and Leipsic but 23. In American cities the waste of water is enormous and to purify one gallon for drinking and household uses and nine gallons for flushing water-closets, watering streets and extinguishing fires

must ever be a wasteful process to say the least. Many towns in this country are now using water purified by artificial means with apparent satisfaction but I do not think that the time has come when it can be said that such purification is practicable in all cases. Certain methods, like the Anderson process, give excellent results under favorable conditions, but competent engineers have not recommended them for American cities. Sedimentation, coagulation, filtration, aeration all these have passed the experimental stage and are in a sense practical, but that processes involving so much manipulation can be advantageously employed in treating the enormous volumes of water required by large cities, especially where pumping is also necessary, is not as yet demonstrated. As regards filtration alone, it may be said that in our climate the filter beds which give satisfactory results in many parts of Europe cannot generally be employed to advantage, and that this method of filtration has been by no means uniformly successful even in Europe. In a recent report, Dr. Theobald Smith has called attention to the fact that in the Berlin epidemic of typhoid in 1889, "the distribution of the disease was identical with that of the filtered river water" the filter beds being worked with great rapidity to make up for a deficiency in the water supply and the filtered water containing at times 4,000 bacteria per cubic centimeter. In discussing this case he says: "These facts go far to prove that polluted water, when immediately delivered for consumption even after filtration, is not wholly safe. They likewise make prominent the fact while filtration largely rids a given water of its bacteria, it is a process requiring the utmost care, the most constant attention, not only on the part of the engineer, but also of the chemist and bacteriologist. We are furthermore convinced" he adds, "by these experiments that surface water which shows very little, if any pollution, and which is stored before use, is safer than filtered water which before filtration is being manifestly contaminated with sewage." As regards methods of rapid filtration under pressure, combining chemical treatment of the water, generally by alum, as well, various systems are in use in this country, controlled by individuals or companies employing a

variety of patented devices. Granting that the results in some cases seem to be excellent, I think the time has not yet come when they can be unhesitatingly recommended for the purification, in all cases, of large city supplies. I know of no city with a population of one hundred thousand that is using such a process to-day. That numerous infectious diseases are conveyed by water admits of no dispute. In my opinion it is vastly better to purify our sewage before discharging it into the streams which supply us with water, or keep it out of them if practicable altogether, than to attempt to purify the water which it pollutes. Chemical treatment and filtration may be practicable and efficient in certain cases, but I believe that the statement by the Rivers Pollution Commission of England, more than twenty years ago, in their sixth report is as true now as it was then: "Nothing short of the abandonment of the inexpressibly nasty habit of mixing human excrement with our drinking water can confer upon us immunity from the propagation of epidemics through the medium of potable water." The cities of this country may eventually be driven to methods of artificial purification of their water supplies, but it cannot be said that the conditions necessitating such action generally exist as yet. In most cases the safer and more economical course will be found to be either the securing of an unpolluted water, if such be available, or the protection from pollution of existing sources of supply.

